ENGINEERING IN ADVANCED RESEARCH SCIENCE AND TECHNOLOGY

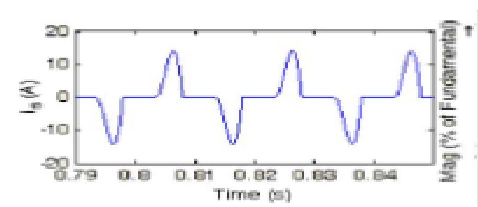
ISSN 2278-2566
Vol.02, Issue.03
December -2018
Pages: -902-909

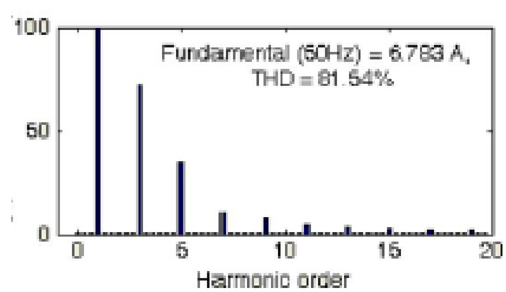
DC MOTOR CONTROL USING BUMP LESS CONTROL FOR TORQUE RIPPLE REDUCTION

1. V. ANIL KUMAR, 2.M.V. LAKSHMAIAH
1. M. Tech Student, Dept. Of EEE, ABR College of Engineering and Technology, Kanigiri , A.P
2. Guide, Dept. Of EEE, ABR College of Engineering and Technology, Kanigiri , A.P

ABSTRACT: This paper deals with a Cuk dc–dc converter as a single-stage power-factor-correction converter for a permanent magnet (PM) brushless dc motor (PMBLDCM) fed through a diode bridge rectifier from a single-phase ac mains. A three-phase voltage-source inverter is used as an electronic commutator to operate the PMBLDCM driving an air-conditioner compressor. The speed of the compressor is controlled to achieve optimum air-conditioning using a concept of the voltage control at dc link proportional to the desired speed of the PMBLDCM. The stator currents of the PMBLDCM during step change in the reference. speed are controlled within the specified limits by an addition of a rate limiter in the reference dc link voltage. The proposed PMBLDCM drive (PMBLDCMD) is designed and modeled, and its performance is evaluated in Matlab–Simulink environment. Simulated results are presented to demonstrate an improved power quality at ac mains of the PMBLDCMD system in a wide range of speed and input ac voltage. Test results of a developed controller are also presented to validate the design and model of the drive. Higher frequency noises are easily damped out by enclosing the motors in absorbent materials which unfortunately have little effect on lower frequencies. The acoustic noise levels of the motor can be reduced by sensing the current draw and controlling the input voltage without adding hardware non typical to the system. In short, the only feedback data available to the controller is the current draw.

INTRODUCTION: THE use of a permanent-magnet (PM) brushless dc motor (PMBLDCM) in low-power appliances is increasing because of its features sof high efficiency, wide speed range, and low maintenance [1]–[4]. It is a rugged three-phase synchronous motor due to the use of PMs on the rotor. The commutation in a PMBLDCM is accomplished by solid state switches of a three-phase voltage-source inverter (VSI). Its application to the compressor of an air-conditioning (Air-Con) system results in an improved efficiency of the system if operated under speed control while maintaining the temperature in the airconditioned zone at the set reference consistently. The Air-Con exerts constant torque (i.e., rated torque) on the PMBLDCM while operated in speed control mode. The Air-Con system with PMBLDCM has low running cost, long life, and reduced mechanical and electrical stresses compared to a single-phase

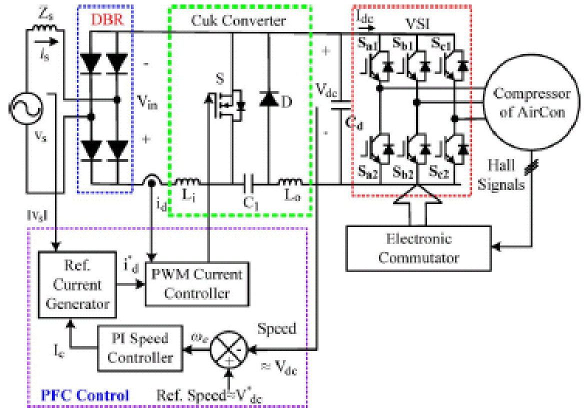




Current waveform at ac mains and its harmonic spectra for the PMBLDCM drive (PMBLDCMD) without PFC.

induction motor-based Air-Con system operating in "on/off" control mode. A PMBLDCM has the developed torque proportional to its phase current and its back electromotive force (EMF), which is proportional to the speed . Therefore, a constant current in its stator windings with variable voltage across its terminals maintains constant torque in a PMBLDCM under variable speed operation. A speed control scheme is proposed which uses a reference voltage at dc link proportional to the desired speed of the permanent-magnet brushless direct current (PMBLDC) motor. However, the control of VSI is only used for electronic commutation based on the rotor position signals of the PMBLDC motor. The PMBLDCMD is fed from a single-phase ac supply through a diode bridge rectifier (DBR) followed by a capacitor at dc link. It draws a pulsed current as shown in Fig. 1, with a peak higher than the amplitude of the fundamental input
current at ac mains due to an uncontrolled charging of the dc link capacitor. This results in poor power quality (PQ) at ac mains in terms of poor power factor (PF) of the order of 0.728, high total harmonic distortion (THD) of ac mains current at the value of 81.54%, and high crest factor (CF) of the order of 2.28. Therefore, a PF correction (PFC) converter among various available converter topologies is almost inevitable for a PMBLDCMD. Moreover, the PQ standards for low power equipments, such as emphasize on low harmonic contents and near unity PF current to be drawn from ac mains by these drives.

There are very few publications regarding PFC in PMBLDCMDs despite many PFC topologies for switchedmode power supply and battery charging applications. This paper deals with an application of a PFC converter for the speed control of a PMBLDCMD. For the proposed voltagecontrolled drive, a Cuk dc–dc converter is used as a PFC converter because of its continuous input and output currents, small output filter, and wide output voltage range as compared to other single switch converters . Moreover, apart from PQ improvement at ac mains, it controls the voltage at dc link for the desired speed of the Air-Con. The



detailed
Control scheme of the proposed Cuk PFC converter-fed VSI-based PMBLDCMD. modeling, design, and performance evaluation of the proposed drive are presented for an air-conditioner driven by a 0.816-kW 1500-r/min PMBLDC motor Permanent magnet brushless DC motors (PMBLDCMs) are considered as better option in various low power (less than 5 kW) applications due to their energy efficiency and ease of control [1-3]. The PMBLDCM is a three-phase synchronous motor with permanent magnets (PMs) on the rotor. The commutation in a PMBLDCM is accomplished by solid state switches of a three-phase voltage source inverter (VSI). The combination of VSI and PMBLDCM is referred as PMBLDCM drive [4-10]. The efforts of researchers towards improvement in the performance of traditionally used motors such as induction motors, DC motors and synchronous motors has opened up new application areas of the PMBLDCMD. Moreover, the advancements in power electronics and digital signal processors (DSPs) have added many features to the PMBLDCM drives to make them preferred choice for various industrial installations The most commonly used topology for PMBLDCMD fed from single-phase AC mains uses a diode bridge rectifier (DBR) followed by a smoothening DC capacitor . It draws an uncontrolled charging current for the DC capacitor resulting in a pulsed current from the AC mains as resulting in various power quality (PQ) disturbances at AC mains such as poor power factor (PF), increased total harmonic distortion (THD) of AC mains current and its high crest factor (CF). The power quality (PQ) disturbances at AC mains of a PMBLDCMD are

represented in terms of various power quality indices such as PF, CF, total harmonic distortion (THDi) of AC mains current, displacement power factor (DPF) and ripples in DC link voltage (@Vdc).

. Current waveform at AC mains and its harmonic spectra for the PMBLDCMD topology shown in Fig. 1 These PQ disturbances result in transformer and neutral conductor heating, heating of motors and cables, EMI, power supply failure (brownout or blackout) and component failure. Reduction of harmonic currents and voltage distortion at AC mains with near unity PF are referred as power factor correction (PFC) and mitigation of PQ disturbances. Various DC –DC converters are operated as PFC converters for variety of applications. The performance of a PFC converter is evaluated on the basis of these PQ indices. For the monitoring and mitigation of these PQ problems in the low power applications, there are international standards such as. These standards emphasize on low harmonic contents and near unity power factor current to be drawn from AC mains by various loads. As reported in the literature , the PFC converter topologies in various commercial applications possess two-stages of DC-DC converters. A boost DC-DC converter is used as a power factor pre-regulator (PFP) at the front-end followed by second stage DC-DC converter for voltage regulation. The second converter is usually a flyback or a forward converter for low power application (less than 1 kW) and a full-bridge converter for higher power applications (1-5kW). However, the high cost and complexity in operation of two DC-DC converters are the constraints of the two stage PFC converters resulting in the use of a single stage PFC converter in many applications. Moreover, the additional cost and complexity of two-stage PFC is not justified for low power applications, therefore, the converter topologies with features of PFC as well as voltage regulation in single stage are preferred in the PMBLDCM drives. There are many DC-DC converter topologies e.g. buck, boost, buck-boost, Ćuk, SEPIC, zeta, push-pull, half bridge and full bridge, reported in the literature for general purpose loads, which can be modeled and designed for PMBLDCM drives. There are various control strategies reported in the literature for PFC. This paper primarily focuses on the two control strategies which are based on current multiplier control and voltage follower control due to their inherent advantages of PFC with other added

features. The current multiplier control is further investigated in terms of peak current control and average current control for PFC at AC mains. The current multiplier control uses continuous conduction mode (CCM) operation of the PFC converters as shown in , whereas, the voltage follower control uses discontinuous conduction mode (DCM) operation of PFC converters The current multiplier control requires additional sensors for input current (id) and supply voltage (vs). High-frequency PWM and hysteresis current control techniques are usually employed for the current control loop and wide-bandwidth controllers in voltage loop to provide fast response and desired PQ at input AC mains. The current multiplier control results in current control at input AC mains and DC link voltage control of the PMBLDCM drives along with improved power quality at AC mains. The voltage follower control has been reported in the literature with a variety of applications such as switched mode power supplies (SMPS) and electronic ballasts, due to inherent advantages of PFC with reduced sensors and single control loop, however, it has a disadvantage of increased peak current rating of the solid state switches.

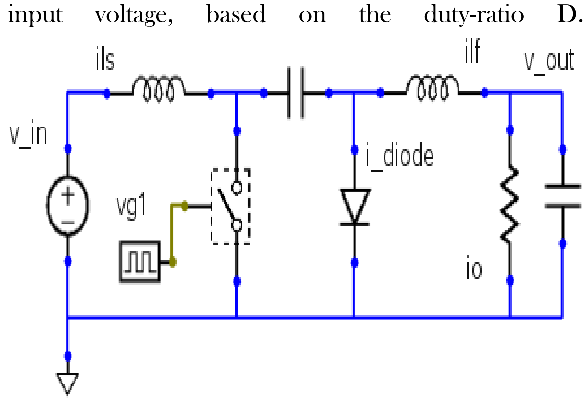
CUK CONVERTER :

The main applications of this circuit are in regulated dc power supplies, where a negative polarity output may be desired with respect to the common terminals of the input voltage and the average output is either higher or lower than the dc input voltage. The typical scematic circuit for the Cut Converter is as shown in Fig. 1. The capacitor C1 acts as a primary means to store and transfer the power from input to output. The voltage vc1 is always greater than either input or output voltage. The average output to input relations are similar to that of a buck-boost converter circuit. The output voltage is controlled by controlling the switch-duty cycle. The ratio of output voltage to input voltage is given by

$$\frac{V_o}{V_{in}} = D \cdot \frac{1}{1-D} = \frac{I_{in}}{1_o} \tag{1}$$

Where, Vo and Vin are the output and input voltages, respectively. The term Io and Iin

are the output and input currents, respectively. The term D is the duty ratio and de_ned as the ratio of the on time of the switch to the total switching period. This shows the output voltage to be hgher or lower than the input voltage, based on the duty-ratio D.



The Schematic circuit for the cu'k converter

Sample Plots The sample simulation plots are shown in Fig. 2. Here, the _rst upper plot shows the gate driver pulse. The second plot shows the input and output voltages. The third plot shows the switch current, diode current and the source current. All the plots are steady and plotted for one cycle with reference to the time scale. Few sample exercises are given here to get the complete understanding of the topic.

AIR-CONDITIONING:

DEFINITION:

In the broadest sense air conditioning can refer to any form of cooling, heating, ventilation or disinfection that modifies the condition of air, typically for thermal comfort. The more common use of *air conditioning* is to mean cooling and often dehumidification of indoor air, typically via refrigeration. An air conditioner (*AC* or *A/C* in North American English, *aircon* in British and Australian English) is an appliance, system, or mechanism designed to extract heat from an area using a refrigeration cycle. The most common uses of modern air conditioners are for comfort cooling in buildings and transportation vehicles.

Air-Conditioning Systems:

Depending on applications, there are several options / combinations of air conditioning, which are available for use:

- Air conditioning (for space or machines)
- Split air conditioners
- Fan coil units in a larger system
- Air handling units in a larger system.

PMBLDCMD

The PMBLDCMD consists of an electronic commutator, a VSI, and a PMBLDCM.

Electronic Commutator: The electronic commutator uses signals from Hall-effect position sensors to generate the switching sequence for the VSI

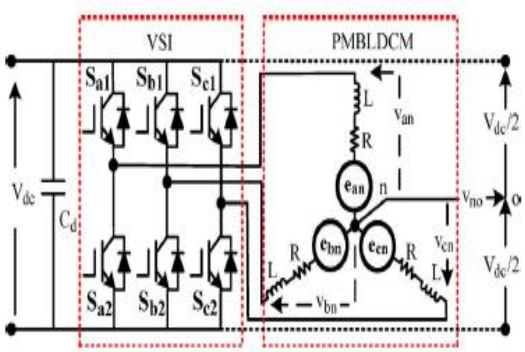


Fig. 3. Equivalent circuit of a VSI-fed PMBLDCMD.

VSI: The output of VSI to be fed to phase "a" of the PMBLDC motor is calculated from the equivalent circuit of a VSI-fed PMBLDCM

$$v_{ao} = (V_{dc}/2) \quad \text{for } S_{a1} = 1 \tag{12}$$

$$v_{ao} = (-V_{dc}/2) \quad \text{for } S_{a2} = 1 \tag{13}$$

$$v_{ao} = 0 \quad \text{for } S_{a1} = 0, \text{ and } S_{a2} = 0 \tag{14}$$

$$v_{an} = v_{ao} - v_{no} \tag{15}$$

where $v$ao, $v$bo, $v$co, and $v$no are the voltages the three phases (a, b, and c) and neutral point (n) with respect to the virtual midpoint of the dc link voltage shown as "o" in Fig. 3. The voltages $v$an, $v$bn, and $v$cn are the voltages of the three phases with respect to the neutral terminal of the motor (n), and Vdc is the dc link voltage. The values 1 and 0 for Sa1 or Sa2 represent the "on" and "off" conditions of respective IGBTs of the VSI. The voltages for the other two phases of the VSI feeding the PMBLDC motor, i.e., $v$bo, $v$co, $v$bn, and $v$cn, and the switching pattern of the other IGBTs of the VSI (i.e., Sb1, Sb2, Sc1, and Sc2) are generated in a similar way.

3) PMBLDC Motor: The PMBLDCM is modeled in the form of a set of differential equations [11] given as

$$v_{an} = \mathrm{R}i_a + p\lambda_a + e_{an} \tag{16}$$

$$v_{bn} = \mathrm{R}i_b + p\lambda_b + e_{bn} \tag{17}$$

$$v_{cn} = \mathrm{R}i_c + p\lambda_c + e_{cn}. \tag{18}$$

In these equations, p represents the differential operator (d/dt), ia, ib, and ic are currents, λa, λb, and λc are flux linkages, and $e$an, $e$bn, and $e$cn are phase-to-neutral back EMFs of PMBLDCM, in respective phases; R is the resistance of motor windings/phase. Moreover, the flux linkages can be represented as

$$\lambda_a = L_s i_a - M(i_b + i_c) \tag{19}$$

$$\lambda_b = L_s i_b - M(i_a + i_c) \tag{20}$$

$$\lambda_c = L_s i_c - M(i_b + i_a) \tag{21}$$

where Ls is the self-inductance/phase and M is the mutual inductance of PMBLDCM winding/phase. The developed torque Te in the PMBLDCM is given as

$$T_e = (e_{an}i_a + e_{bn}i_b + e_{cn}i_c)/\omega_r \tag{22}$$

where ωr is the motor speed in radians per second.

Since PMBLDCM has no neutral connection

$$i_{\mathrm{a}} + i_{\mathrm{b}} + i_{\mathrm{c}} = 0. \qquad (23)$$

From (15)–(21) and (23), the voltage (v_{no}) between the neutral point (n) and midpoint of the dc link (o) is given as

$$v_{\mathrm{no}} = \left\{v_{\mathrm{ao}} + v_{\mathrm{bo}} + v_{\mathrm{co}} - \left(e_{\mathrm{an}} + e_{\mathrm{bn}} + e_{\mathrm{cn}}\right)\right\}/3. \qquad (24)$$

From (19)–(21) and (23), the flux linkages are given as

$$\lambda_{\mathrm{a}} = (L_s + M)i_{\mathrm{a}}, \quad \lambda_{\mathrm{b}} = (L_s + M)i_{\mathrm{b}}, \quad \lambda_{\mathrm{c}} = (L_s + M)i_{\mathrm{c}}. \qquad (25)$$

From (16)–(18) and (25), the current derivatives in generalized state-space form are given as

$$\mathrm{pi}_x = (v_{\mathrm{xn}} - i_x R - e_{\mathrm{xn}})/(L_s + M) \qquad (26)$$

where x represents phase a, b, or c. The back EMF is a function of rotor position (θ) as

$$e_{\mathrm{xn}} = K_b f_x(\theta)\omega_r \qquad (27)$$

where x can be phase a, b, or c and accordingly $f_x(\theta)$ represents a function of rotor position with a maximum value ± 1, identical to trapezoidal induced EMF, given as

$$f_{\mathrm{a}}(\theta) = 1 \qquad \text{for } 0 < \theta < 2\pi/3 \qquad (28)$$
$$f_{\mathrm{a}}(\theta) = 1\left\{(6/\pi)(\pi - \theta)\right\} - 1 \qquad \text{for } 2\pi/3 < \theta < \pi \qquad (29)$$
$$f_{\mathrm{a}}(\theta) = -1 \qquad \text{for } \pi < \theta < 5\pi/3 \qquad (32)$$
$$f_{\mathrm{a}}(\theta) = \left\{(6/\pi)(\pi - \theta)\right\} + 1 \qquad \text{for } 5\pi/3 < \theta < 2\pi. \qquad (31)$$

The functions $f_b(\theta)$ and $f_c(\theta)$ are similar to $f_a(\theta)$ with phase differences of 120◦ and 240◦, respectively. Therefore, the electromagnetic torque expressed as

$$T_e = K_b\left\{f_{\mathrm{a}}(\theta)i_{\mathrm{a}} + f_{\mathrm{b}} + f_{\mathrm{c}}(\theta)i_{\mathrm{c}}\right\}. \qquad (32)$$

The mechanical equation of motion in speed derivative form is given as

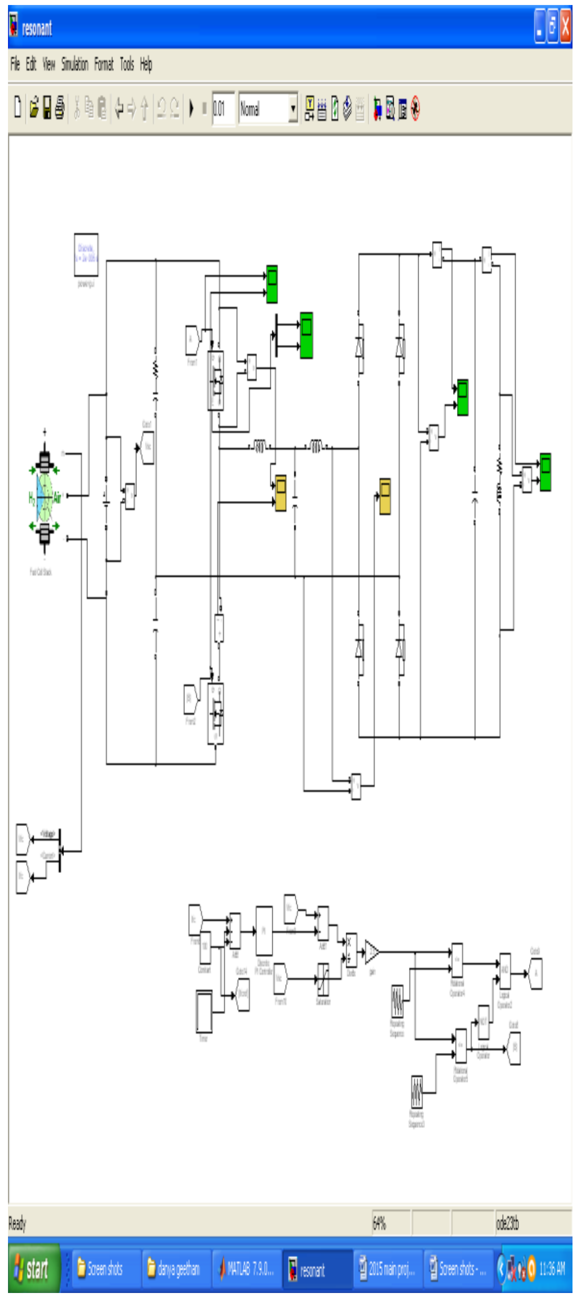
$$p\omega_r = (P/2)(T_e - T_l - B\omega_r)/(J) \qquad (33)$$

where ωr is the derivative of rotor position θ, P is the number of poles, Tl is the load torque in newton meters, J is the moment of inertia in kilogram square meters, and B is the friction coefficient in newton meter seconds per radian.
The derivative of rotor position is given as

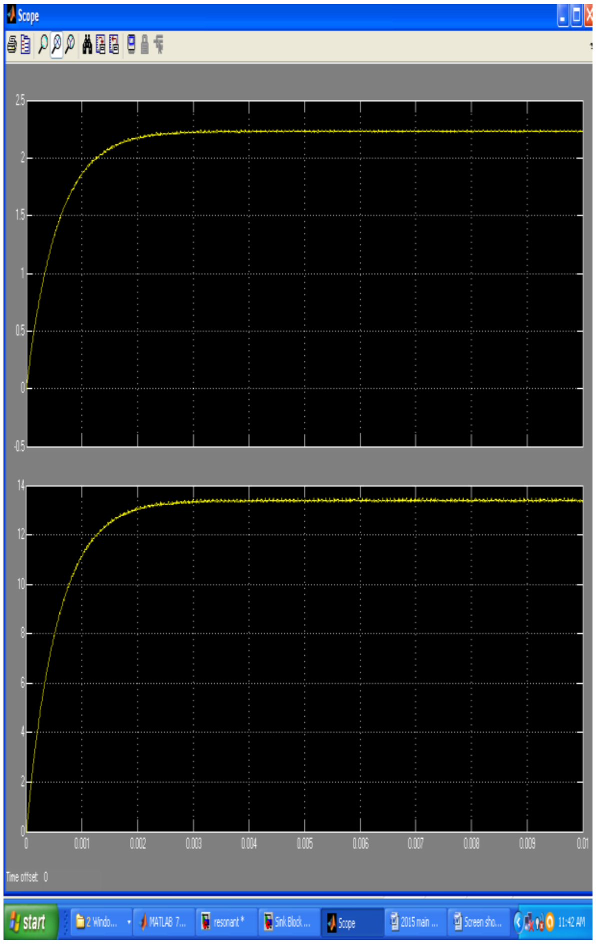
$$p\theta = \omega_r. \qquad (34)$$

Equations (16)–(34) represent the dynamic model of the PMBLDC
motor.

CIRCUIT DIAGRAM:



RESULT:



Current vs Voltage

CONCLUSION:

A new speed control strategy for a PMBLDCMD using the reference speed as an equivalent voltage at dc link has been simulated for an air-conditioner employing a Cuk PFC converter and experimentally validated on a developed controller. The speed of PMBLDCM has been found to be proportional to the dc link voltage; thereby, a smooth speed control is observed while controlling the dc link voltage. The introduction of a rate limiter in the reference dc link voltage effectively limits the motor current within the desired value during the transient conditions. The PFC Cuk converter has ensured near unity PF in a wide range of the speed and the input ac voltage. Moreover, PQ indices of the proposed PFC drive are in conformity to the International Standard.The proposed PMBLDCMD has been found as a promising variable speed drive for the Air-Con system. Moreover, it may also be used in the fans with PMBLDC motor drives on the trains recently introduced in Indian Railways. These PMBLDC motor drivebased fans have similar PQ problems as they use a simple single-phase diode rectifier and no speed control. These fans also have inrush current problems. All these PQ problems of poor PF, inrush current, and speed control in these fans on the trains in Indian Railways may be mitigated by the proposed voltage-controlled PFC Cuk converter-based PMBLDCMD. Enhancement technique is implemented with optimizing parameters using generic efficiency.

REFERENCES:

[1] T. Kenjo and S. Nagamori, *Permanent Magnet Brushless DC Motors*. Oxford, U.K.: Clarendon, 1985.
[2] T. J. Sokira and W. Jaffe, *Brushless DC Motors: Electronic Commutation and Control*. New York: Tab, 1989.
[3] J. R. Hendershort and T. J. E. Miller, *Design of Brushless Permanent- Magnet Motors*. Oxford, U.K.: Clarendon, 1994.
[4] J. F. Gieras and M. Wing, *Permanent Magnet Motor Technology—Design and Application*. New York: Marcel Dekker, 2002.
[5] B. Singh, B. N. Singh, A. Chandra, K. Al-Haddad, A. Pandey, and D. P. Kothari, “A review of single-phase improved power quality ac–dc converters,” *IEEE Trans. Ind. Electron.*, vol. 50, no. 5, pp. 962–981, Oct. 2003.
[6] N. Mohan, M. Undeland, andW. P. Robbins, *Power Electronics: Converters, Applications and Design*. Hoboken, NJ: Wiley, 1995.
[7] *Limits for Harmonic Current Emissions (Equipment Input Current ≤ 16 A Per Phase)*, Int. Std. IEC 61000-3-2, 2000.
[8] S. Cuk and R. D. Middlebrook, “Advances in switched-mode power conversion Part-I,” *IEEE Trans. Ind. Electron.*, vol. IE-30, no. 1, pp. 10–19, Feb. 1983.
[9] C. J. Tseng and C. L. Chen, “A novel ZVT PWM Cuk power factor corrector,” *IEEE Trans. Ind. Electron.*, vol. 46, no. 4, pp. 780–787, Aug. 1999.
[10] B. Singh and G. D. Chaturvedi, “Analysis, design and development of single switch Cuk ac–dc converter for low power battery charging application,” in *Proc. IEEE PEDES*, 2006, pp. 1–6.
[11] C. L. Puttaswamy, B. Singh, and B. P. Singh, “Investigations on dynamic behavior of permanent magnet brushless dc motor drive,” *Elect. Power Compon. Syst.*, vol. 23, no. 6, pp. 689–701, Nov. 1995.